CT-Derived Lesion Descriptors of Intracranial Haemorrhage and their Association with Injury Severity and Outcome

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I. INTRODUCTION

Traumatic brain injury (TBI) is one of the leading causes of death and disability globally. Intracranial haemorrhage (ICH) is one of the most common sequelae of TBI, resulting in mass lesions due to disrupted blood vessels and damage to surrounding brain tissue. Current prognostic models, such as TBI-IMPACT [1], primarily rely on demographic and clinical variables and do not explicitly capture the biomechanical characteristics of haemorrhagic lesions. Recent automatic segmentation tools, such as BLAST-CT [2], enable in-depth biomechanical analysis of ICH. Through the development of spatial and morphological lesion descriptors, relationships between patient-specific lesions and outcomes can be explored to elucidate the role that biomechanics plays in TBI.

II. METHODS

Approximately 600 ICH patients were selected from the CENTER-TBI dataset [3] based on predefined inclusion criteria. Early clinical CT scans were processed using an automated segmentation pipeline that combined BLAST-CT for haemorrhage segmentation with TotalSegmentator [4] for whole-brain and skull extraction. BLAST-CT has previously been validated on the CENTER-TBI database, but a sanity visual inspection was performed for this study nonetheless. The same visual inspection was carried out for TotalSegmentator.

Binary segmentation masks were used to derive quantitative lesion descriptors. Morphological descriptors included lesion volume and radiomics-derived shape characteristics. Spatial descriptors were calculated using lesion centre-of-mass positions relative to approximate anatomical reference points, e.g. brainstem, derived from the brain segmentation. Additional metrics were normalised to account for inter-patient differences in brain volume.

III. INITIAL FINDINGS

The automated pipeline successfully processed the majority of CT scans (n=597) from the selected cohort. As a result, lesion and brain masks were created for each participant, and biomechanical descriptors could be extracted.

TABLE 1

RESULTS OF KRUSKAL-WALLIS TESTS FOR GLASGOW OUTCOME SCALE – EXTENDED (GOSE) GROUPINGS (FAVOURABLE ≥ 5, UNFAVOURABLE 2–4, DEAD = 1)

Descriptor	H	p-value	η^2
Log Lesion Volume (norm.)	66.9	2.91e-15	0.397
Lesion Sphericity	54.9	1.18e-12	0.325
Lesion-Brain CoM Distance (norm.)	32.0	1.11e-07	0.187
Lesion-Brainstem Distance (norm.)	15.9	3.52e-04	0.09

TABLE 2

RESULTS OF KRUSKAL-WALLIS TESTS FOR GLASGOW COMA SCALE (GCS) CATEGORIES (MILD ≥ 13, MODERATE 9–12, SEVERE ≤ 8)

Descriptor	H	p-value	η^2
Log Lesion Volume (norm.)	52.2	4.55e-12	0.26
Lesion Sphericity	48.6	2.76e-11	0.242
Lesion-Brain CoM Distance (norm.)	26.5	1.78e-06	0.129
Lesion-Brainstem Distance (norm.)	7.41	0.025	0.0325

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Preliminary analysis demonstrated significant differences in lesion morphological and spatial descriptors across outcome groups using Kruskal-Wallis testing (Table I; all $p < 0.05$). Dunn post-hoc testing with Bonferonni correction (Fig. 1) identified significant pairwise differences between favourable and dead outcomes, and between favourable and unfavourable outcomes for lesion volume, sphericity, and spatial distance measures. No significant differences were observed between dead and unfavourable groups. Similar differences were observed across Glasgow Coma Scale categories (Table II). Lesion elongation and fragmentation index were not significantly associated with outcome.

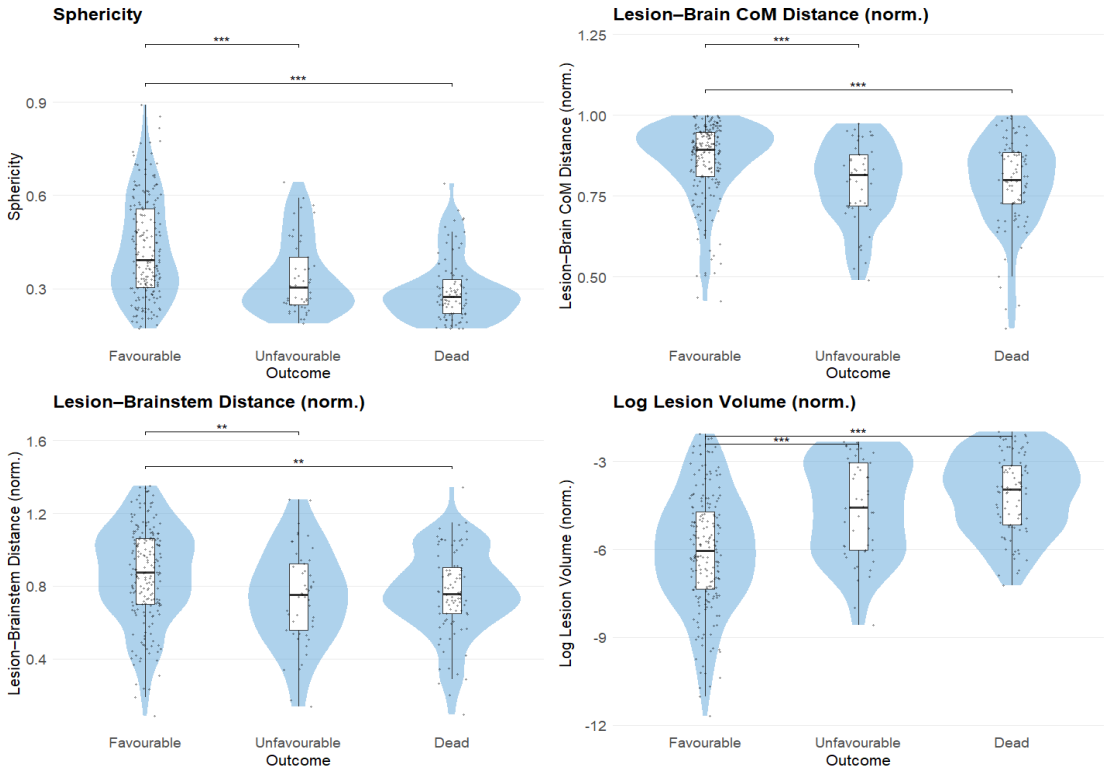

Fig 1: Violin plots demonstrating significant differences in the shape and location of the lesions across the outcome groups. Pairwise differences (Dunn post-hoc test) are indicated by asterisks: *** $p < 0.001$, ** $p < 0.05$, no asterisk = not significant.

IV. DISCUSSION

This study demonstrates that morphological and spatial descriptors derived from routine CT imaging can capture meaningful differences across both outcome and injury severity groups. Lesion volume, sphericity, and spatial proximity to brain structures were consistently associated with both GOSE and GCS groups, suggesting that these features reflect underlying injury mechanisms not captured by conventional clinical variables alone. Having a lower sphericity and being more centrally located may reflect a more complex haemorrhage geometry and involvement of critical anatomical regions, with potential implications for intracranial pressure dynamics and secondary injury progression.

The automated pipeline was used to extract descriptors from across the dataset, demonstrating the viability of this approach for inclusion in modelling frameworks. Although these results are preliminary and further work is ongoing, these results suggest that biomechanical features could be used alongside existing clinical predictors for prognostic modelling of TBI. Future work will focus on this challenge of model integration and on evaluating the added value of incorporating biomechanical features.

V. REFERENCES

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